CLAIMS

1. A method of testing the hearing of a subject, the method comprising the steps of:

(a) creating a test signal having an exponential modulated component;

(b) transducing the test signal to create an acoustic stimulus;

(c) presenting the acoustic stimulus to the subject;

(d) sensing potentials from the subject while substantially simultaneously presenting the acoustic stimulus to the subject; and

(e) analyzing the potentials to determine whether the potentials comprise data indicative of the presence of at least one steady-state response to the acoustic stimulus.

2. The method of claim 1, wherein the test signal comprises at least one of an amplitude component and a frequency component, the at least one of the amplitude component and the frequency component being exponentially modulated.

3. The method of claim 1, wherein the test signal comprise transient components.

4. The method of claim 3, wherein the transient components are sufficiently periodic to evoke responses having a degree of overlap.

5. An apparatus for testing the hearing of a subject comprising:

(a) a signal creator adapted to create a test signal with an exponential modulated component;

(b) a transducer electrically coupled to the processor and adapted to transduce the test signal to create an acoustic stimulus and present the acoustic stimulus to the subject;

(c) a sensor adapted to sense potentials from the subject while the acoustic stimulus is substantially simultaneously presented to the subject; and

(d) a processor electrically coupled to the sensor and adapted to receive the potentials and analyze the potentials to determine if the potentials comprise data indicative of at least one response to the acoustic stimulus.

6. The apparatus of claim 5, wherein the test signal comprises at least one of an amplitude component and a frequency component, the at least one of the amplitude component and the frequency component being exponentially modulated.

7. The apparatus of claim 5, wherein the test signal comprises transient components.

8. The apparatus of claim 7, wherein the transient components are sufficiently periodic to evoke responses having a degree of overlap.

9. A method of analyzing potentials to determine whether the potentials comprise data indicative of the presence of at least one steady-state response to an acoustic stimulus, wherein the method comprises the steps of:

(a) presenting an acoustic stimulus to a subject;

(b) sensing potentials from the subject while substantially simultaneously presenting the acoustic stimulus to the subject to obtain a plurality of data points;

(c) transforming the plurality of data points into a second plurality of data points;

(d) biasing the second plurality of data points with an expected phase value to obtain a plurality of biased data points; and,

(e) applying a statistical test to the plurality of biased data points to detect the response.

10. A method of analyzing electroencephalogram (EEG) data to determine whether the data are indicative of the presence of at least one steady-state response to a steady-state evoked potential (SSAEP) stimulus, the method comprising the steps of:

(a) presenting a SSAEP stimulus to a subject;

(b) sensing EEG data from the subject while substantially simultaneously presenting the stimulus to the subject;

(c) forming at least one sweep from the EEG data;

(d) calculating a plurality of Fourier components for the sweep.

(e) biasing the Fourier components with an expected phase value to obtain a plurality of biased components; and

(f) applying a statistical test to the plurality of biased data points to detect the response.

11. The method of claim 10, wherein the step (e) comprises the steps of:

(g) calculating the amplitude (ai) and phase (qI) for the plurality of Fourier components;

(h) biasing the amplitudes (ai) to obtain biased data points (pi) according to the formula:

$$pi = ai*\cos(qI - qe)$$

wherein qe is the expected phase value.

12. The method of claim 10, wherein the step (f) comprises the steps of:

(i) calculating upper confidence limits using a one tailed Student t-test on biased amplitudes which represent noise in the vicinity of Fourier components where the response should occur; and,

(j) comparing biased amplitudes of Fourier components where the response should occur to the upper confidence limits to determine if the biased amplitudes are larger than the upper confidence limits.

13. The method of claim 10, wherein the expected phase value is obtained from a database of normative expected phase values correlated to subject characteristics and stimulus characteristics.

14. The method of claim 10, wherein the expected phase value is obtained from previous testing on the subject.

15. The method of claim 10, wherein the stimulus contains other components for which responses are detected and the expected phase value is obtained from extrapolation of the phase values for the detected responses.

16. A method of objectively testing the hearing of a subject, wherein the method comprises the steps of:

(a) selecting an auditory test to be administered to the subject;

(b) creating a test signal comprising at least one component for the auditory test;

(c) transducing the test signal to create a stimulus

(d) presenting the stimulus to the subject;

(e) sensing a potential from the subject while substantially simultaneously presenting the stimulus to the subject; and,

(f) analyzing the potential to detect a response.

17. The method of claim 16, wherein the stimulus comprises a steady-state evoked potential stimulus.

18. The method of claim 16, wherein the acoustic stimulus comprises a stimulus having transient components.

19. The method of claim 18, wherein the transient components comprise at least one of tone pips and clicks.

20. The method of claim 18, wherein the transient components are sufficiently periodic to evoke responses having a degree of overlap.

21. The method of claim 16, wherein the stimulus has an "on" duration and an "off" duration.

22. The method of claim 21, wherein the "on" duration and the "off" duration are automatically controlled.

23. The method of claim 21, wherein the "on" duration and the "off" duration are manually controlled.

24. The method of claim 21, wherein the "off" duration corresponds to a subject recovery period.

25. The method of claim 16, wherein the auditory test is an aided hearing test which comprises the following steps:

(g) providing the subject with a hearing aid;

(h) performing steps (b) to (f);

(i) automatically adjusting the settings of the hearing aid for at least one frequency region which is substantially similar to at least one frequency region of a component in the test signal for which a response was not detected in step (e); and,

(j) performing steps (h) and (i) until a specified number of steady-state responses have been detected in the potentials, the specified number which may be chosen by the medical personnel, or which may be chosen automatically based upon the unaided audiometric profile of the subject or from appropriate normative values obtained for similar stimuli.

26. The method of claim 25, wherein the step (i) comprises adjusting the gain of the hearing aid for a frequency region which is substantially similar to the frequency region of a component in the test signal for which a response was not detected.

27. The method of claim 16, wherein the test signal comprises noise masking.

28. The method of claim 27, wherein the noise masking comprises one of white noise, pink noise, band-pass noise and band-pass spectra noise.

29. The method of claim 16, wherein the auditory test comprises a supra-threshold test comprising an intensity limen test and the test signal comprises an amplitude modulated component having a modulation depth of approximately 100%, wherein the intensity limen test comprises the steps of:

(k) performing steady state evoked potential testing while minimizing the modulation depth of the test signal upon each detected response to determine a minimum modulation depth at which a response is detected; and,

(l) comparing the minimum modulation depth with a database of normative minimum modulation depths to obtain an indication of the status of the auditory system of the subject.

30. The method of claim 29, wherein the supra-threshold test comprises a frequency limen test and the test signal comprises an amplitude modulated component having a frequency modulation depth, wherein, the frequency limen test comprises the steps of:

(m) determining a minimum modulation depth at which a response is detected; and,

(n) comparing the minimum modulation depth with a database of normative minimum modulation depths to obtain an indication of the status of the auditory system of the subject.

31. The method of claim 16, wherein the auditory test is an auditory threshold test and wherein the auditory threshold test comprises the step of:

(o) iteratively carrying out steps (c) to (e) at several intensity levels in order to determine a minimal stimulus intensity for which a response is detected for each component of the test signal.

32. The method of claim 16, wherein the auditory test is an auditory threshold test and the test signal comprises two or more combined amplitude modulation and frequency modulation signals having carrier frequencies which are separated by at least one-half octave, wherein, each combined amplitude modulation and frequency modulation signal has a frequency modulated component and an amplitude modulated component wherein at least the envelope of each combined amplitude modulation or frequency modulation signal is modulated by an exponential modulation signal.

33. The method of claim 16, wherein the auditory test is conducted for a maximum time limit.

34. The method of claim 33, wherein the maximum time limit is adjusted depending on an amount of noise in the potentials.

35. The method of claim 16, wherein a component of the test signal is changed based upon the response and a recording criteria.

36. The method of claim 35, wherein the recording criteria comprise an amount of noise in the potentials.

37. The method of claim 35, wherein the component of the test signal is changed automatically.

39. The method of claim 35, wherein the component of the test signal is changed manually.

40. The method of claim 35, further comprising the step of indicating to a test administrator the status of at least one of the response and the recording criteria.

41. The method of claim 40, wherein the step of indicating comprises at least one of providing a visual indicator and an audio indicator.

42. The method of claim 16, wherein the auditory test comprises upwardly adjusting the intensities of components in the test signal which tend to evoke responses having smaller amplitudes, so that all components in the stimulus evoke responses having similar amplitudes.

43. An apparatus for objectively testing the hearing of a subject comprising:

(a) a selector adapted for selecting an auditory test to perform on the subject;

(b) a signal creator electrically coupled to the selector and adapted to create an appropriate test signal comprising at least one component for the test;

(c) a transducer electrically coupled to the signal creator and adapted to transduce the test signal to create an acoustic stimulus and to present the acoustic stimulus to the subject;

(d) a sensor adapted to sense potentials from the subject while the acoustic stimulus is substantially simultaneously presented to the subject;

(e) a processor electrically coupled to the sensor and adapted to receive the potentials and analyze the potentials to determine if the potentials comprise data indicative of at least one response to the acoustic stimulus; and

(f) an interface adapted to operably couple the processor to a programmable hearing aid, the programmable hearing aid having a plurality of programmable gain factors, the interface operable to communicate programming data from the processor to the programmable hearing aid based on at least one detected response to at least one component of the acoustic stimulus.

44. An iterative adaptive staircase method for automatically obtaining frequency specific threshold estimation for one or more acoustic stimuli presented to a subject comprising the steps of:

(a) presenting to the subject at least one acoustic stimulus to evoke at least one steady-state response from the subject while simultaneously recording electroencephalograph (EEG) data from the subject;

(b) statistically assessing the presence of at least one steady-state response in the EEG data;

(c) repeating steps (a) and (b) until a recording criterion is reached;

(d) decreasing the intensity of the at least one acoustic stimulus a specified amount;

(e) repeating steps (a), (b), (c) and (d) for a specified range of intensities; and

(f) generating summary results based upon the absence of a steady-state response at one or more intensities.

45. The method of claim 44, wherein the recording criterion is a noise level based upon the intensity of the acoustic stimuli.

46. The method of claim 44, wherein the step (d) comprises decreasing the intensity of a component of the at least one acoustic stimulus.

47. The method of claim 44, wherein the step (d) comprises decreasing the intensity of the at least one acoustic stimulus a specified amount if the steady-state response associated with the at least one acoustic stimulus was detected and maintaining the intensity or increasing the intensity of the at least one acoustic stimulus a specified amount if the steady-state response associated with the at least one acoustic stimulus was failed to be detected.

48. The method of claim 44, wherein step (b) comprises:

(g) creating an n by m table where each cell of the table contains an index with values of the sweep numbers for each stimulus at each intensity level; and

(h) detecting a response to each stimulus at each intensity level by averaging data in a particular cell of the table.

49. An iterative adaptive staircase method for obtaining frequency specific threshold estimation for two or more simultaneously presented stimuli comprising the steps of:

(a) presenting at least two acoustic stimuli to a subject, each of which evoke a steady-state response in the subject;

(b) recording electroencephalograph (EEG) data from the subject until a recording criterion is reached;

(c) decreasing the intensity of each of the at least two acoustic stimuli a specified amount;

(d) repeating steps (a), (b) and (c) until a stopping criteria is met; and

(e) generating summary results based upon failure to detect a steady-state response at one or more intensities.

50. The method of claim 49 wherein step (c) comprises decreasing the intensity of each stimulus for which a corresponding steady-state response has been detected and has fulfilled a recording criteria.

51. The method of claim 49, wherein the recording criteria comprises reaching significance and staying significant for a specified amount of time.

52. The method of claim 49 wherein a recording criterion is selected to be one of: a level of residual background noise; a level of residual background noise proximate to the frequency of at least one steady-state response which is being evaluated; a time limit; an absolute time limit; a time limit based upon normative values for similar stimuli and intensities; and a time limit based upon an estimate of background noise levels estimated from at least part of the total recorded data.

53. The method of claim 49 wherein the recording criterion is based upon the intensity level of the stimulus, and is chosen based upon at least one

of: a normative database; previously recorded data of the subject; and a combination of a normative database and previously recorded data of the subject.

54. The method as described in claim 49 wherein step (c) comprises decreasing the intensity of each stimulus which has been detected and has reached a recording criteria or increasing the intensity of a stimulus for which a response has failed to be detected.

55. A method of testing the hearing of a subject, the method comprising the steps of:

(a) creating a periodic test signal, the period being sufficient to evoke responses having a degree of overlap;

(b) transducing the test signal to create an acoustic stimulus;

(c) presenting the acoustic stimulus to the subject;

(d) sensing potentials from the subject while substantially simultaneously presenting the acoustic stimulus to the subject; and

(e) analyzing the potentials to determine whether the potentials comprise data indicative of the presence of at least one steady-state response to the acoustic stimulus.

56. The method of claim 55, wherein the test signal comprises a modulated signal having at least one of slopes steeper than sine wave modulated signal slopes and regions between maxima having less energy than corresponding regions of a sine wave modulated signal.

57. The method of claim 55, wherein the test signal comprises transient components.

58. The method of claim 55, wherein the transient components are sufficiently periodic to evoke responses having a degree of overlap.

59. The method of claim 55, wherein the test signal has an "on" duration and an "off" duration.

60. The method of claim 59, wherein the "on" duration and the "off" duration are automatically controlled.

61. The method of claim 59, wherein the "on" duration and the "off" duration are manually controlled.

62. The method of claim 59, wherein the "off" duration corresponds to a subject recovery period.

63. A method of testing the hearing of a subject, the method comprising the steps of:

(a) presenting at least one acoustic stimulus to the subject to evoke at least one steady-state response from the subject while simultaneously recording electroencephalograph (EEG) data from the subject;

(b) statistically assessing whether at least one steady-state response was present in the EEG data;

(c) repeating steps (a) and (b) until a recording criterion is reached;

(d) repeating steps (a), (b), and (c) for a specified range of intensities;

(e) determining the stimulus intensity to be above a specified level;

(f) altering the testing procedure when the stimulus intensity exceeds the specified level; and

(g) repeating steps (a)-(e) until the detection of at least one said response has occurred or until a recording criteria has been met.

64. The method of claim 63, wherein the step of altering the testing procedure comprises automatically pausing for a specified time period.

65 The method of claim 63, wherein the step of altering the testing procedure comprises presenting an alternate acoustic stimulus to the subject.

66. The method of claim 63, wherein the step of altering the testing procedure comprises automatically switching to between two or more acoustic stimuli to be tested.

67. The method of claim 63, wherein the step of altering the testing procedure comprises presenting the acoustic stimulus for a "on" duration and ceasing presentation of the acoustic stimulus for an "off" duration.

68. A method of objectively testing the hearing of a subject, wherein the method comprises the steps of:

(a) selecting an auditory test to be administered to the subject;

(b) creating a test signal comprising at least two modulation signals having carrier frequencies separated by approximately one-half an octave;

(c) transducing the test signal to create a stimulus

(d) presenting the stimulus to the subject;

(e) sensing a potential from the subject while substantially simultaneously presenting the stimulus to the subject;

(f) analyzing the potential to detect a response;

(g) decreasing the intensity of a modulation signal of the test signal that elicited a response that was detected;

(h) iteratively repeating steps (c)-(g) for a specified period of time or until a specified noise floor has been achieved; and

(i) determining a minimal stimulus intensity for which a response was detected for each stimulus based upon the response data.